Performance Comparison of M-PSK and M-QAM Modulations for WiMAX OFDM system under the Rayleigh Fading Channel

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Abstract With the increasing bandwidth and number of users of wireless communication demand of higher bitrates system for wireless digital transmissions has also increased. Since number of users are increasing thus the capacity of the wireless communication is a major challenge. WiMAX is widely used to serve this purpose. The wireless WiMAX communications are based on OFDM technique with IEEE 802.16e standards. .In this paper, the performance of the M-PSK modulation methods is compared with the M-QAM modulation for wireless WiMAX over the Rayleigh fading channels. The FFT size is kept constant to 64 for performance evaluation. The bit error rate is used as the performance evaluation parameter. Also the effect of the varying the Doppler shifts frequencies on the performance of OFDM under Rayleigh fading have also evaluated. Performance is also compared for different transmitting gains.

Keywords: OFDM; WiMAX; QAM; Multipath Fading; Bit error rate.

I. INTRODUCTION

The notion of gender difference is a popular concept in The increasing growth of the wireless network has created the demand for new communication techniques which can be efficiently used at the higher data rates. WiMAX is widely used to serve this purpose. Fading and inter symbol interference are the major problems with wireless WiMAX transmission. OFDM is used as solution for this problem [13]. With the increasing wireless network user's, efficient bandwidth utilization is the major technical challenge. Therefore, many modulation techniques have been designed to improve the higher data rates [8, 18]. Performance of these modulation techniques must be analyzed in order to provide the quality wireless transmissions in varying fading channel environments.

There are many challenges exist at every level of the overall wireless system design viz. hardware, at communication channel, and network and application design. Some of the major challenges are discussed here are: performance of channel under increasing number of modulation channels, and effect of the Doppler shift on the system performance under the multipath fading channel [4].

The multiple input multiple output (MIMO) Orthogonal frequency division multiplexing OFDM [6], has become the next generation wireless broadband technology. It has gained great popularity due to its capability of high rate transmission and also due to its robustness against Multi-path fading. Many modulation techniques have been used by the researchers with OFDM. Neetu sood et al. [3] has used BPSK and QPSZK modulation techniques with OFDM over Gama fading channel. Jigisha et al.[18] have compared M-PSK with M-QAM for AWGN channel. QAM modulation is most widely used in mobile wireless digital transmission [1, 3, 11, and 14]. Studies of existing methods show that QAM scheme effectively improves the BER performance over a flat fading channel [9]. But, when the digital data is transmitted through a frequency selective fading channel, then the performance of these QAM is greatly affected by inter-symbol interference (ISI). Therefore, it is required to combine the QAM modulation with multicarrier OFDM schemas in order to improve the performance.
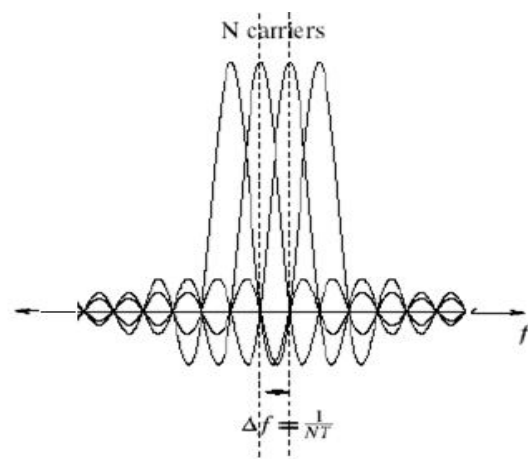

Figure 1.   OFDM frequency responses

In the conventional multi-carrier communication methods, spectrum of each sub carrier is non-overlapping and the

frequency of interest are extracted using band pass filtering, while on the other hand, in OFDM the frequency spacing between sub-carriers are generated such that sub-carriers are mathematically orthogonal to each other as shown in the Fig. 1. Although the spectra of sub-carriers overlap each other but every individual sub-carrier can be easily extracted by simple base band processing. This overlapping phenomenon makes OFDM more spectral efficient and secure than the other multicarrier communication technologies. The IEEE 802.16e WiMAX wireless standards are based on OFDM [9, 10] in order to give better performance in non line of sight communication environments.

Prime objective of this paper is to simulate and analyze the OFDM using the physical layer specification of IEEE 802.16e. Analyze the performance of OFDM with different digital modulation techniques for mobile WiMAX system. It is also to analyzing the effect of the OFDM system under the different Doppler shifts. Performance is evaluated based on the simulated Bit-Error-Rate (BER), and Signal-to-Noise Ratio (SNR). Since different digital modulation scheme under different fading channel provides the different BER performance. Therefore it is desired to analyze the performance of the OFDM system under the variable flat and frequency selective fading environments.

II. FADING

In every wireless transmission channels signal travels through multiple path due to reflection of signal by physical structures like buildings, or mountains, creating multiple signal paths between the base station and the user terminal [7]. These multipath signals can interfere with the desired signal and causes reduction in signal strength occurs. Such type of reduction is called a fade; and the phenomenon is known as "Rayleigh fading" The fading phenomenon randomly varies during the transmission. The major factors which are responsible for signal fading are Doppler shift, scattering, reflection, and diffraction. These phenomenon exists due to, relative velocity of trance-receivers, atmospheric ducting, ionosphere reflection, and due to refraction and reflection from terrestrial objects. The most common fading model is the Rayleigh fading.

A. Rayleigh Fading Channel

Rayleigh fading channel may be a very useful model within heavily built-up or congested cities where there is no line of sight between the transmitter and receiver. In the Rayleigh fading model, it is assumed that the channel induces amplitude, which varies in time according to the Rayleigh distribution [15]. The Rayleigh distribution is the most widely used distribution to describe the received envelope value of a signal $z(t) = |x(t)|$ at any time t is given as

$$p_z x = \frac{x}{\sigma^2} e^{\left(\frac{-x^2}{2\sigma^2}\right)} (x \geq 0) \qquad (1)$$

The Rayleigh distribution of a received complex envelope [7] Where

$$E(x^2) = 2\sigma^2 \text{ and x is generally} \geq 0 \qquad (2)$$

In Rayleigh distribution, x is transmitted signal and σ is the root man square value of the received. $P_x x == $ voltage

signal before envelope detection, and σ^2 is the time average power of the received signal before envelope detection. the time-average power of the received signal before envelope detection. It is well known that the envelope of the sum of two Quadrature Gaussian noise signals obeys a Rayleigh distribution. This fading distribution could be described as follows:

- This represents the worst fading case because it do not consider having Line of-Sight (LOS) between sender and receiver.

- It is caused by Doppler-shifted echoes with a Gaussian distribution,

- The power is exponentially distributed.

- The phase is uniformly distributed and independent from the amplitude.

III. OFDM TRANSMITTER

The block diagram of the proposed OFDM trans-receiver system is described in the Figure 2. Before transmitting information bit over a selected channel through the OFDM transmitter, system implement the M-QAM modulation schemes on the input bit stream. Using QAM modulation techniques the transmitter section converts the digital data to be transmitted, into a mapping of the sub carrier's amplitude and phases.
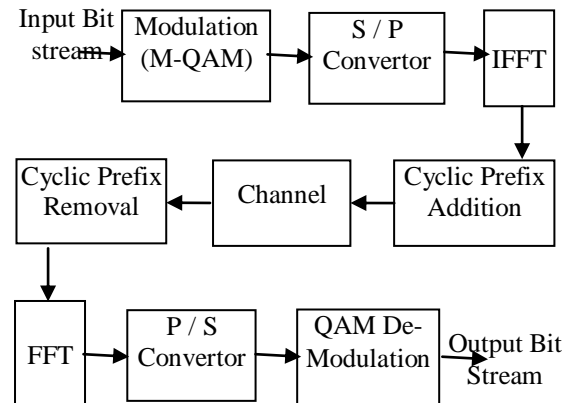

Figure 2 Block Diagram of the proposed OFDM transmitter

A serial to parallel (S/P) convertor converts the serial data stream into N parallel multiple sub-carriers streams. The spectral representation of the sub-carriers data is then transformed into the time domain by using an IFFT block which is computationally more efficient. This in turns introduces the orthogonality between multiple sub carriers in OFDM system.

In order to reduce the interferences between OFDM symbols (ISI) and also OFDM carriers (ICI), a guard time is introduced for each OFDM symbol after the IFFT [2], which is cyclically extended within this guard time, as shown in Figure 3. This cyclical extension is called the cyclic prefix (CP). Therefore, equalization at the receiver becomes very simple task. This often motivates the use of OFDM in wireless systems.
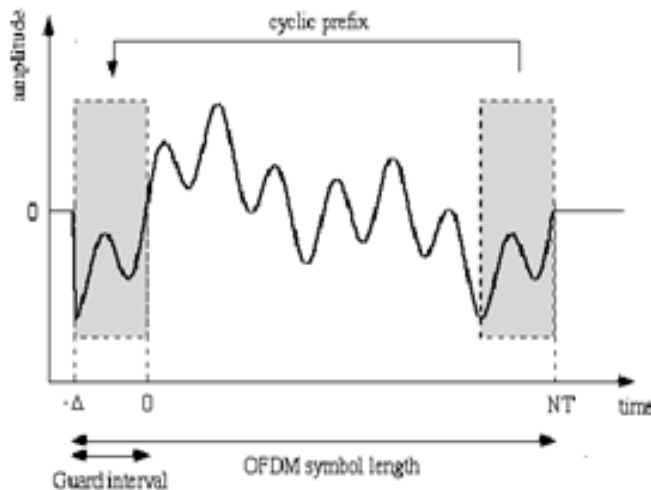
Figure 3 Cyclic prefix insertions [6],

IV. CHANNELS

In this paper channel is modeled for Flat and Frequency selective fading channels.

A. Flat fading Model

The Rayleigh flat fading channel model assumes that all the components that make up the resultant received signal are reflected or scattered and there is no direct path from the transmitter to the receiver.

B. Frequency selective Fading model

In frequency-selective fading, the coherence bandwidth of the channel is smaller than the bandwidth of the signal [12]. Different frequency components of the signal therefore experience de-correlated fading Frequency selective fading is a radio propagation anomaly caused by partial cancellation of a radio signal by itself, means the signal arrives at the receiver by two different paths, and at least one of the paths is changing (lengthening or shortening). This typically happens in the early evening or early morning as the various layers in the ionosphere move

In the Rayleigh flat fading channel model, it is assumed that the channel induces amplitude, which varies in time according to the Rayleigh distribution. When the channel impulse response is modelled as a zero-mean complex-valued Gaussian process, the envelope at any instant is Rayleigh distributed. After the time domain signal passes through the channel, it is divided into the parallel symbols and the prefix is simply discarded. The receiver performs the reverse operation to that of the transmitter. The amplitude and phase of the sub-carrier are then selected and converted back to digital data

The spectral representation of the sub-carriers data is then transformed into the time domain using an IFFT which is computationally more efficient. This introduces the orthogonality between multi-carriers. The cyclic prefix is added to each symbol to removes both ISI and inter-carrier interference (ICI) effects [6]. The digital data is then transmitted over the channel. The channel may be AWGN, Rayleigh or Ricians channel. After the time domain signal passes through the channel, it is divided into the parallel symbols and the prefix is simply discarded. The receiver

performs the reverse operation to that of the transmitter. The amplitude and phase of the sub-carrier are then selected and converted back to digital data

V. SIMULATION PARAMETERS

Various experiments have been performed by varying the simulation parameters to evaluate the performance of the simulated OFDM system. Effect of Doppler shifts, multipath gains, and various number of PSK phases M, are evaluated in this paper. The MATLAB is used as tool to develop, analyze, and simulate the OFDM trans-receiver under the Rayleigh fading channel. The simulation and design parameters are given in the Table 1.

TABLE I. INPUT PARAMETERS

Variable	Value	Description
Nbitpersym	52	Number of bits per OFDM Symbol
Nsym	10^4	Number of symbols
len_fft	64	Size of the FFT
sub_car	52	Number of OFDM data sub-carriers
EbNo	0 to 40	Range of SNR
Fd	100 Hz	Maximum Doppler Shift
H	Channel	Rayleigh fading channel
D	[0 to 1e-6]	Path Delays
N	800000	Number of samples processed

VI. EXPERIMENTAL RESULTS

In this paper performance of the various M-PSK modulation techniques are compared with the M-QAM modulation techniques. Where, M represents the number of PSK phases or PSK size, which is varied as 2, 4, 16, 256, 512 and 1024. The performance of the modulation methods for OFDM system is compared for the Rayleigh fading channel based on the bit error rate (BER) for different signal to noise power levels.

A. Over Flat Fading Channel

Figure 4 shows the performance comparison of the various M-PSK modulations with the 16 QAM modulation techniques. It can be observed that at the lesser number of phases (2-16) the PSK modulation techniques gives better BER performance than QAM over OFDM system. But as Number of Phases increases beyond the range, BER for M-PSK also increases and the BER with 256 PSK is even higher than the BER with 16 QAM.

Figure 5 compares the performance of the M-PSK and M-QAM for higher value of M (256-1024) as used with wireless WiMAX. Increasing the QAM size not only improves the capacity of wireless system but also reduces the error probability as compared to the M-PSK. The lowest bit error rate is achieved at the 1024 QAM thus QAM is widely used with WiMAX applications. Also it can be observed that as the number of phases increasing the BER of the M-PSK gets poorer.
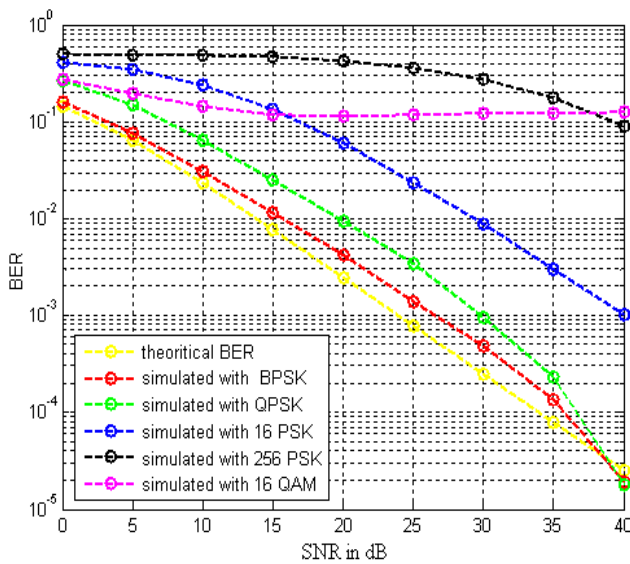
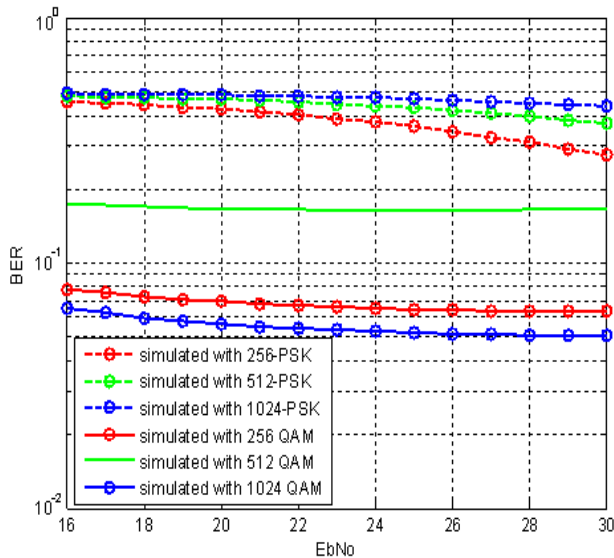Figure 4 Comparison of BER performances of M-PSK and 16 QAM-OFDM

Figure 6 Comparison of BER performances for different Doppler shift for 2566 QAM-OFDM

Figure 5 Comparison of BER performances of M-PSK and M-QAM-OFDM for wireless WiMAX
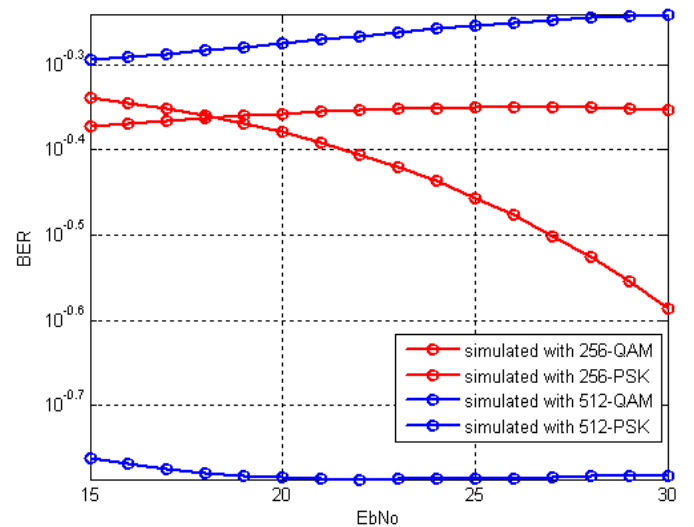
Figure 7 Comparison of BER of M-PSK and M-QAM-OFDM for multipath fading wireless WiMAX

The effect of Doppler shift on the system performance is compared for 256 QAM by varying the maximum Doppler shift frequency from 50-250 Hz as in the Figure 6. It is found that as the Doppler shift is increased the performance of BER reduces slowly. It is clear from the Figure 6 that, the minimum BER is achieved at the maximum Doppler shift of 200 Hz at the 20 dB gain as used in wireless mobile communication. This is corresponding to average speed of around 60-70 kmph.

Frequency Selective Multipath Fading Channel

Figure 7 shows the comparison of PSK with QAM for Multipath frequency selective fading channel. The four multiple path having the delay vectors and Gain vectors as of D= 1.0e-004 * [0 0.0400 0.0800 0.1200] and G= [0 -3 -6 -9] respectively. It is observed that as the M increases 256 the performance of the QAM have significant improvement over the PSK.

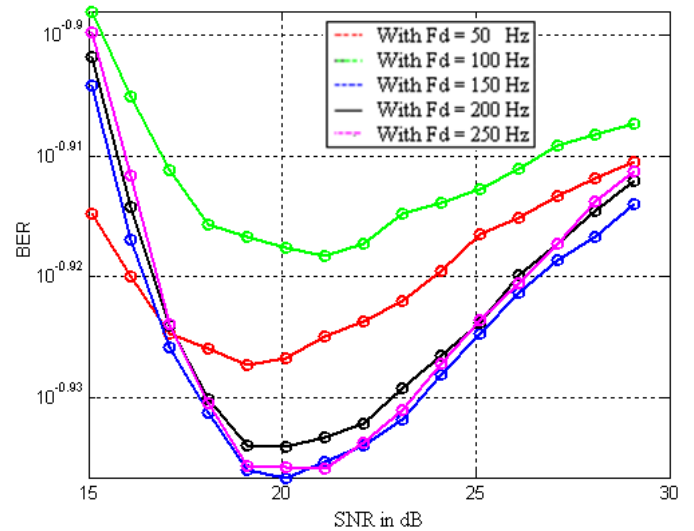## VII. CONCLUSION

In the paper, the performance evaluation of the WiMAX IEEE 802.16e over the multipath Rayleigh fading channels using QAM-OFDM is presented. The performance of the OFDM system is compared by varying the size of the QAM modulation. The BER performance of OFDM improves with increasing size of QAM modulation. The Doppler shift must be kept minimum and, sampling time must be as high as possible in order to achieve the better performance of the system.

In further future adaptive cyclic prefix length and FFT size may be used which improves the performance much better. The performance of Rayleigh fading channel may be compared with the Racian fading channel in future.

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